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Closed Orbit Distortion and Correction in the 248 Meter SNS Accumulator Ring Lattice

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The SNS accumulator ring lattice has evolved considerably since the last calculations [1] of COD (Closed Orbit Distortion) and Correction were done. Following are the results of similar calculations for the current lattice.

1 Lattice Parameters

The current lattice is described in Reference [2]. The elements and layout for one superperiod are shown in Figure 1. Figure 2 shows the Beta Functions and Dispersion for one superperiod. (Here the plot starts at the downstream end of quadrupole QVX9.) Figure 3 shows the same for the entire 248 meter lattice (four superperiods). The horizontal and vertical tunes are $Q_H = 6.3$ and $Q_V = 5.8$.

2 Calculation of COD

We consider the COD due to random errors in the horizontal and vertical placement of the lattice quadrupoles. The error distribution is assumed to be Gaussian with RMS values $\sigma_H = \sigma_V = 0.25$ mm for the horizontal and vertical positions. The MAD code was used to calculate the COD for each of 101 separate distributions of placement errors. A cut-off of $2.5\,\sigma$ was imposed for each distribution (i.e. any errors greater than 2.5 times the RMS value were rejected). The tunes were set to be $Q_H = 6.3$ and $Q_V = 5.8$.

3 Correction of COD

The method of 3-bumps [1, 3, 4] was used to correct the COD for each distribution of quadrupole placement errors. Here, as derived in Ref. [3], the kick required in the jth corrector is given by

$$\phi_j = \left\{ \frac{M_{11}^{(j)}}{M_{12}^{(j)}} + \frac{M_{22}^{(j-1)}}{M_{12}^{(j-1)}} \right\} Y_j - \frac{Y_{j-1}}{M_{12}^{(j-1)}} - \frac{Y_{j+1}}{M_{12}^{(j)}} \tag{1}$$

where $M_{kl}^{(j)}$ are the matrix elements of the transfer matrix from the jth to the $(j+1)$th corrector, and Y_j is the value of the uncorrected COD at the jth corrector. The correctors are treated as point dipoles located 10 centimeters from the ends of the quadrupoles. (The dipole correctors are labeled DVCX1, DHCX2, DVCX3, DHCX4, ..., and so on in Figure 1. Here H and V denote dipoles which kick in the Horizontal and Vertical planes respectively. X denotes the superperiod and C and D stand for "Corrector" and "Dipole".)

4 Results

Figure 4 shows the horizontal (red curve) and vertical (blue curve) COD for one of the 101 distributions of quadrupole placement errors. The dipole corrector kicks required to correct the COD are shown in Figure 5.

Figure 6 shows the extreme values (maximum and minimum) of the horizontal (red) and vertical (blue) COD for the entire ensemble of 101 COD's. Here we see extreme values of -17 and $+13$ mm for the horizontal and vertical COD's respectively. The RMS values for the ensemble of 101 COD's are plotted in Figure 7; note the correlation with the beta functions. Figure 8 shows the extreme values of the horizontal (red) and vertical (blue) kicks required to correct the COD's. Here we see that all kicks are within the range of ± 0.45 milliradians.

The CODs produced by the displacement of a single quadrupole at a time were also examined. Each of the 13 quadrupoles in a superperiod was displaced in turn by 1 mm in the horizontal and vertical planes. The maximum horizontal and vertical corrector kicks required to correct the CODs are listed in Table 1. All kicks are within the range of ± 0.50 milliradians.

5 Dipole Corrector Strength

The integrated strength of the dipole corrector currently under design is

$$BL = \int B\,dl = 7.421 \times 10^{-3}\ \mathrm{Tm} \tag{2}$$

at 13 Amps. For protons with 1 GeV kinetic energy and rigidity $B\rho = 5.6574$ Tm, this gives a kick of

$$\phi = BL/(B\rho) = 1.31\ \text{milliradians} \tag{3}$$

at 13 Amps, which is more than adequate for correcting the errors considered here.

References

[1] C. J. Gardner, "Closed Orbit Distortion and Correction in the Four-Fold Symmetric NSNS Ring", BNL/SNS Tech. Note No. 31, April 17, 1997.

[2] J. Wei (Editor), "Preliminary Change Request for the SNS 1.3 GeV-Compatible Ring", BNL/SNS Tech. Note No. 76, May 4, 2000.

[3] J. Milutinovic and A.G. Ruggiero, "Closed Orbit Analysis for the AGS Booster", Booster Tech Note No. 107, February 1, 1988

[4] B. Autin, "Lattice Perturbations", AIP Conference Proceedings No. 127, American Institute of Physics, (1985) 139–200.

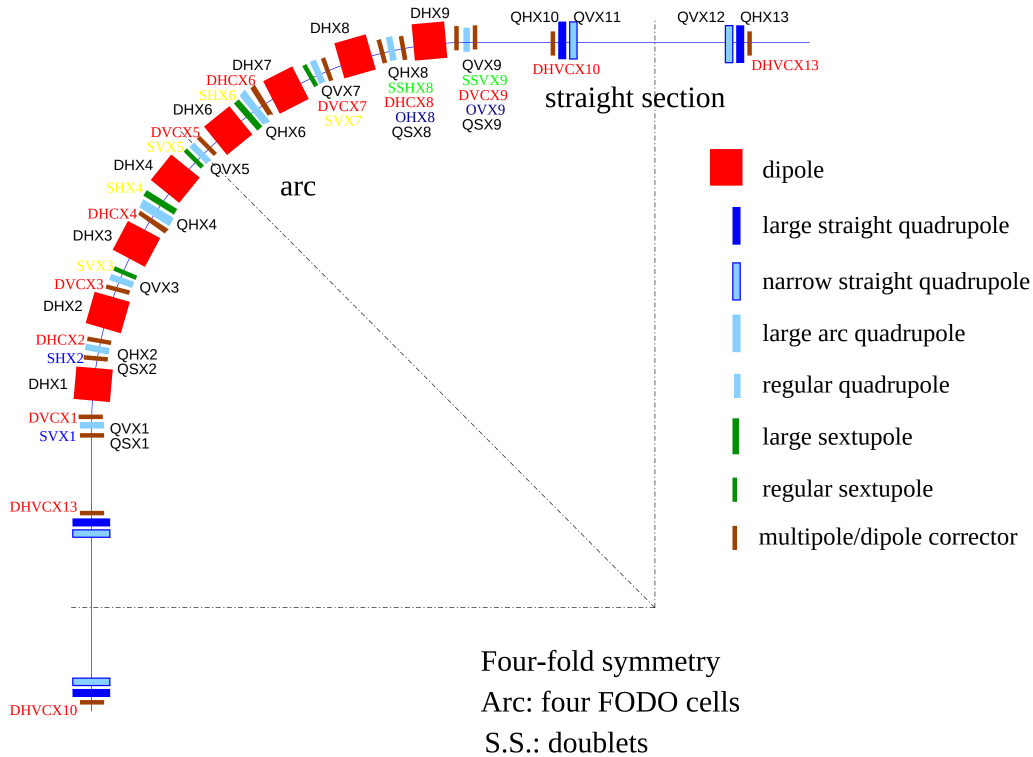

Figure 1: Elements and Layout for One Superperiod of the 248 Meter SNS Accumulator Ring Lattice.

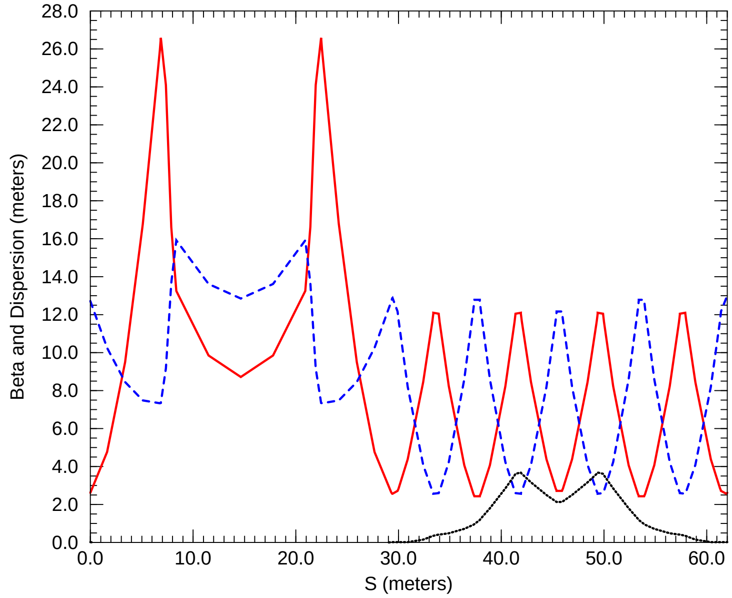

Figure 2: Beta and Dispersion for 1 Superperiod ($Q_H = 6.3$, $Q_V = 5.8$).

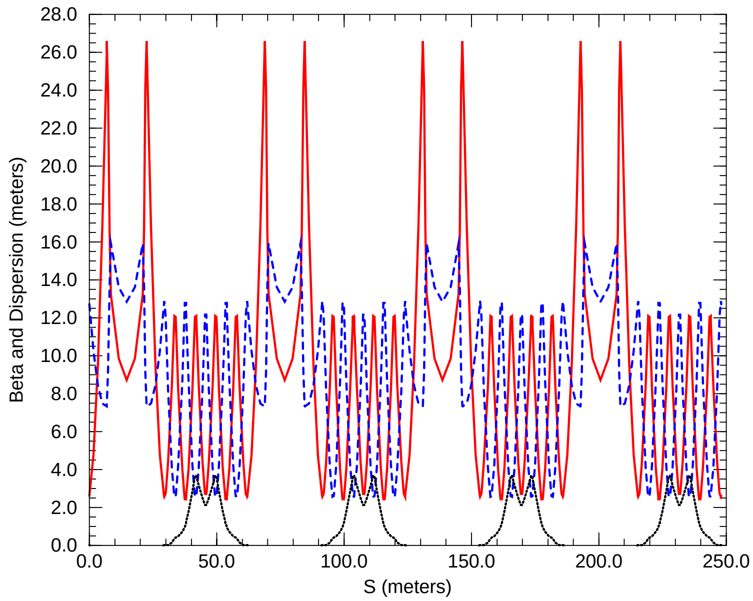

Figure 3: Same for Entire 248 meter Lattice ($Q_H = 6.3$, $Q_V = 5.8$).

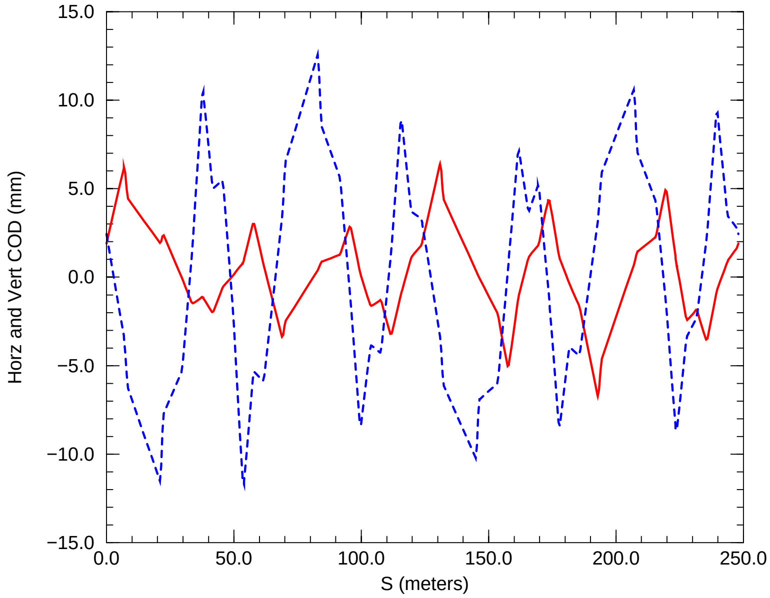

Figure 4: Typical COD due to Quadrupole Displacements.

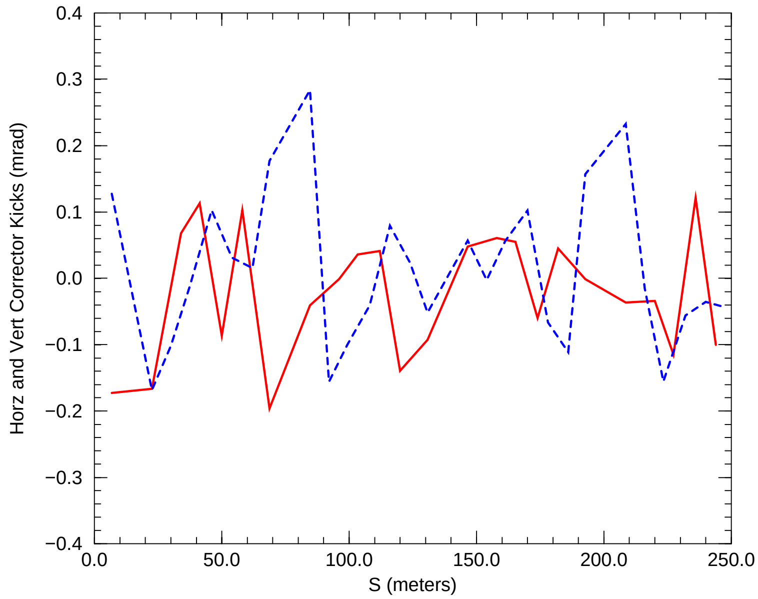

Figure 5: Dipole Kicks Required to Correct COD.

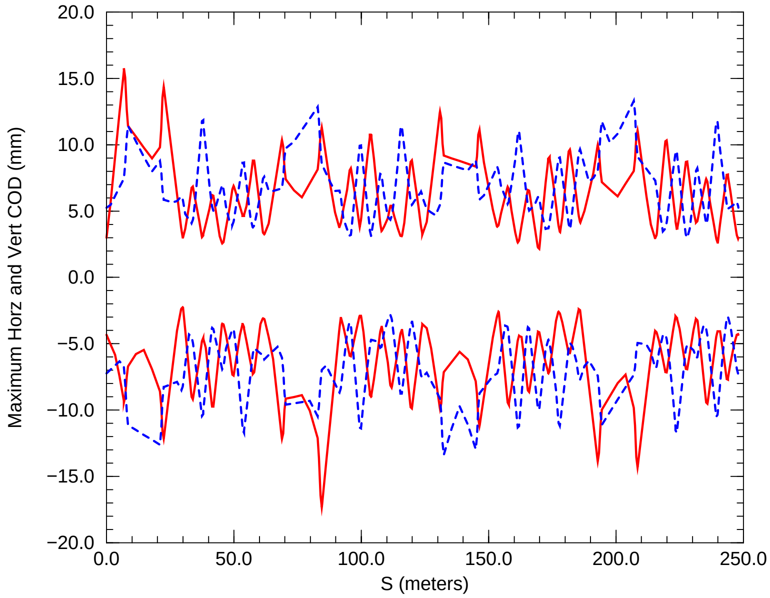

Figure 6: Maximum and Minimum COD For 101 Error Distributions.

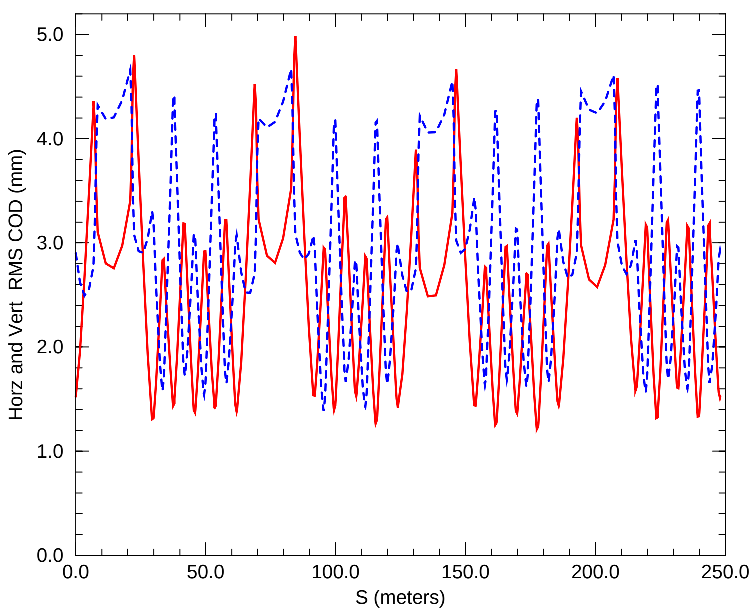

Figure 7: RMS COD for 101 Error Distributions.

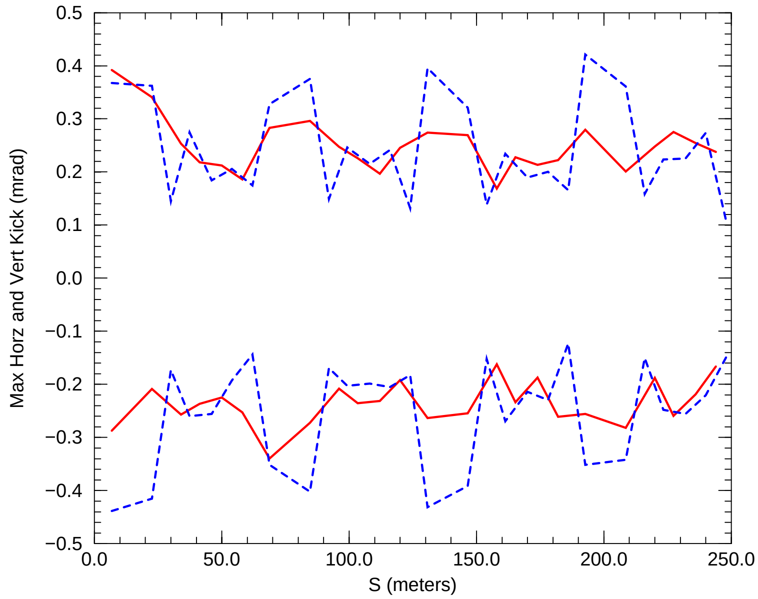

Figure 8: Maximum Kicks Required to Correct CODs.

Table 1: Dipole Kicks vs Quad Displacement

$\Delta x = \Delta y = 1$ mm				
Quad	H Dipole	ϕ_H (mr)	V Dipole	ϕ_V (mr)
QVA1	DHTA2	+0.11	DVTA1	−0.25
QHA2	DHTA2	−0.36	DVTA3	+0.11
QVA3	DHTA2	+0.12	DVTA3	−0.38
QHA4	DHTA4	−0.36	DVTA3	+0.11
QVA5	DHTA6	+0.12	DVTA5	−0.38
QHA6	DHTA6	−0.36	DVTA5	+0.11
QVA7	DHTA6	+0.12	DVTA7	−0.38
QHA8	DHTA8	−0.35	DVTA7	+0.11
QVA9	DHTA8	+0.11	DVTA9	−0.25
QHA10	DHTA10	−0.43	DVTA10	+0.44
QVA11	DHTA10	+0.27	DVTA10	−0.49
QVA12	DHTA13	+0.27	DVTA13	−0.49
QHA13	DHTA13	−0.43	DVTA13	+0.44